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SEALING DEVICE

The present invention relates to a sealing device, in particular for a gas turbine or aircraft engine, according to the definition of the species in Claim 1.

Gas turbines are made up of a plurality of modules, for example a fan, a combustion chamber, preferably a plurality of compressors, as well as a plurality of turbines. In the preferably plurality of turbines, what is involved in particular is a high pressure turbine as well a low-pressure turbine, in the plurality of compressors in particular a high-pressure compressor as well as a low-pressure compressor. In a turbine, as well as in a compressor of a gas turbine, in the axial direction and the flow direction of the gas turbine, a plurality of vane rings are positioned one after another, each vane ring having a plurality of vanes positioned divided over the circumference. Between two respective adjacent vane rings a rotor blade ring is positioned in each case which has a plurality of rotor blades. The rotor blades are assigned to a rotor and rotate together with the rotor with respect to a fixed housing as well as the also fixedly developed vanes of the vane rings.

In order to optimize the efficiency of a gas turbine, leakages, on the one hand, between the rotating rotor blades and the fixed housing and, on the other hand, between the fixed vanes and the rotor have to be avoided by effective sealing systems. Thus, in order to seal such gaps, it is known from the related art that one may assign a honeycomb seal including a plurality of honeycomb seal cells to the stator, that is, the fixed housing or the radially inner ends of the fixed vanes, the honeycomb seal cells being separated from one another by walls. These honeycomb seals in

particular act together with sealing fins assigned to the rotor or the rotating rotor blades, such a sealing fin rotating with respect to the honeycomb seal on the stator side.

According to the related art, the walls that separate the honeycomb cells, of the honeycomb seal, from one another run exactly in the radial direction, so that, for example, the sealing fins are aligned perpendicularly, relatively to the walls of the honeycomb seal cells that run transversely to the direction of rotation of the sealing fins.

When the rotor, particularly the sealing fins, brush(es) against the honeycomb seal on the stator side, the rotor accordingly impacts, in the axial view, the walls of the honeycomb seal cells that run transversely to the direction of rotation of the rotor, whereby a force of resistance is set counter to the rotation or revolution of the rotor. For, walls of the honeycomb seal cells running in such a way are formed to be relatively stiff, and for this reason the walls of the honeycomb seal cells deform virtually not at all. When the rotor, and especially the sealing fins, run into the honeycomb seal, therefore, according to the related art, the walls of the honeycomb seal cells are worn away from place to place. In this situation, accordingly, the honeycomb seal is damaged and the gap to be sealed is enlarged, which altogether is a disadvantage.

Using this as a starting point, the present invention is based on the object of creating a novel sealing device, especially for a gas turbine or an aircraft engine.

This object is attained by a sealing device according to Claim 1. According to the present invention, at least the walls of the honeycomb seal cells that run transversely to the

direction of rotation of the rotor are placed radially at a slant in the direction of rotation of the rotor.

In the sense of the present invention it is provided that at least the walls of the honeycomb seal cells that run transversely to the direction of rotation of the rotor are placed radially at a slant in the direction of rotation of the rotor. According to that, the walls of the sealing cells, in the axial direction of view, no longer run perpendicular to the rotor, especially to the sealing fins, but rather these walls run at a certain angle to the rotor. Thereby, a deformability of the walls of the honeycomb seal cells is made available, so that when the rotor, and especially the sealing fins on the rotor side, brush against the honeycomb seal, a wearing away or a crack formation of the walls is avoided. Using the present sealing device, accordingly an effective sealing of a gap between a rotor and a stator is made possible.

Preferably, the walls of the honeycomb seal cells that run transversely to the direction of rotation of the rotor are placed at a slant, in the direction of rotation of the rotor, in such a way that edges of these walls facing the rotor are offset compared to edges of these walls facing away from the rotor, in the direction of rotation of the rotor. The edges of these walls facing the rotor and/or the edges of these walls facing away from the rotor are arched or run in a straight line.

According to an advantageous further refinement of the present invention, in addition to the walls of the honeycomb seal cells that run transversely to the direction of rotation of the rotor, the walls of the honeycomb seal cells that run in the direction of rotation of the rotor are also placed at a slant.

Preferred further developments of the present invention are derived from the dependent claims and the following description. Exemplary embodiments of the present invention are explained in detail in light of the drawings, without being limited to it. The figures show:

Figure 1 a largely schematic side view in the axial direction of view onto a honeycomb seal including a plurality of honeycomb seal cells of a sealing device according to the related art;

Figure 2 a largely schematic top view in the radial direction of view onto the honeycomb seal including a plurality of honeycomb seal cells as in Figure 1;

Figure 3 a largely schematic side view in the axial direction of view onto a honeycomb seal including a plurality of honeycomb seal cells of a sealing device according to a first exemplary embodiment of the present invention;

Figure 4 a largely schematic top view in the radial direction of view onto the honeycomb seal including a plurality of honeycomb seal cells as in Figure 3;

Figure 5 a largely schematic top view in the radial direction of view onto a honeycomb seal including a plurality of honeycomb seal cells of a sealing device according to a second exemplary embodiment of the present invention; and

Figure 6 a largely schematic top view in the radial direction of view onto a honeycomb seal including a plurality of honeycomb seal cells of a sealing device

according to a third exemplary embodiment of the present invention.

Before we explain in greater detail below exemplary embodiments of the present invention with reference to Figures 3 to 6, let us first describe a sealing device known from the related art with reference to Figures 1 and 2.

Thus, Figures 1 and 2 show in a largely schematic way a honeycomb seal 10 of a sealing device according to the related art, between a rotor (not shown) and a stator (also not shown) of a gas turbine. Figure 1 shows a schematic side view of honeycomb seal 10 in an axial direction of view, and Figure 2 shows a schematic top view of the same in a radial direction of view. The X coordinate of the coordinate system shown visualizes the radial direction, the Y coordinate visualizes the circumferential direction and the Z coordinate visualizes the axial direction. In the axial direction of view according to Figure 1, one is accordingly looking at the X-Y plane, and in the radial direction of view according to Figure 2 one is looking at the Y-Z plane.

Honeycomb seal 10 is formed from a plurality of honeycomb seal cells 11, honeycomb seal cells 11 in Figures 1 and 2 having a rectangular cross sectional area. It should be mentioned at this point that the honeycomb seals could of course also have a hexagonal cross sectional profile.

Honeycomb seal cells 11 of honeycomb seal 10 are bordered by a plurality of walls. Within the meaning of the present invention, we now distinguish between walls that run transversely to or along the direction of rotation of a rotor. The direction of rotation of a rotor (not shown) is clarified in Figures 1 and 2 by an arrow 12. Walls of honeycomb seal cells 11 running transversely to direction of rotation 12 are

characterized by reference numeral 13, and walls of honeycomb seal cells 11 running alongside or parallel to direction of rotation 12 are characterized by reference numeral 14.

As may be seen in Figure 1, according to the related art, walls 13 of honeycomb seal cells 11 running transversely to direction of rotation 12 of the rotor run exactly in the radial direction, so that in the axial direction of view in Figure 1 they are aligned perpendicular to direction of rotation 12 of the rotor. Thus, according to the related art, walls 13 that run transversely to direction of rotation 12, form a resistance for rotor 12, since walls 13 thus developed are relatively stiff, and are able to be only slightly deformed, if at all. When the rotor brushes against walls 13 that run transversely to the direction of its rotation, material is accordingly removed from them, and they are damaged thereby.

Figures 3 and 4 show a honeycomb seal 15 of a sealing device according to the present invention, according to a first exemplary embodiment of the present invention in different representations or directions of view, the directions of view of Figures 3 and 4 corresponding to the directions of view of Figures 1 and 2. Honeycomb seal 15 of Figures 3 and 4 also is made up of a plurality of honeycomb seal cells 16, honeycomb seal cells 16 having a rectangular contour in cross section. Honeycomb seal cells 16 are, in turn, bordered by a plurality of walls which, within the meaning of the present invention, are aligned in optimized fashion relative to the direction of rotation (arrow 17) of a rotor.

In the exemplary embodiment of Figures 3 and 4, walls 18 of honeycomb seal cells 17 that run transversely to the direction of rotation of the rotor are placed radially at a slant in the direction of rotation of the rotor. This can best be inferred

from Figure 3 (corresponds to the axial direction of view), in which the radial slant position of walls 18 is clearly seen. Walls 19, on the other hand, which run alongside or parallel to direction of rotation 17 of the rotor, run radially without such a slanted placement, as in the related art.

Walls 18 of honeycomb seal cells 16 running transversely to direction of rotation 17 of the rotor are, in this context, placed at a slant in such a way that an edge 20 facing the rotor is offset from an edge 21 that faces away from the rotor in the direction of rotation of the rotor, which means that edge 20 facing the rotor, in direction of rotation 17, is positioned forwards of, or downstream from edge 21 that faces away from the rotor. In the top view onto honeycomb seal 10 according to Figure 4 (corresponds to the radial direction of view) edges 20 and 21, that are thus offset, of walls 18 that run transversely to direction of rotation 17 of the rotor, are shown as lines running parallel to each other. Accordingly, edges 20, 21 of walls 18 run in straight lines.

Figures 5 and 6 show two additional exemplary embodiments of honeycomb seals or sealing devices according to the present invention. Since the exemplary embodiments of Figures 5 and 6 essentially correspond to the exemplary embodiment of Figures 3 and 4, the same reference numerals are used for the same modules, to avoid unnecessary repetition.

The exemplary embodiment of Figure 5 differs from the exemplary embodiment of Figures 3 and 4 in that, in the case of honeycomb seal 22 of Figure 5, edges 20, facing the rotor, of walls 18 that run transversely to direction of rotation 17 of the rotor, do not run as straight lines, but rather are curved or arched. The curvature is in direction of rotation 17 of the rotor, in this case. Edges 21, on the other hand, facing away from the rotor, of walls 18 that run transversely

to the direction of rotation of the rotor, run as straight lines. It should be pointed out that, in a difference from the design approach shown in Figure 5, edges 21 facing away from the rotor could also, of course, be executed arched or curved, just as edges 20 of wall 18 that face the rotor.

Figure 6 shows an additional exemplary embodiment of a honeycomb seal 23 according to the present invention, in which, in honeycomb seal 23 according to Figure 6, in addition to walls 18 that run transversely to direction of rotation 17 of the rotor, walls 19 of honeycomb seal cells 16 that run in the direction of rotation of the rotor are also placed at a slant. Thus, in the exemplary embodiment of Figure 6, also in the area of walls 19 that run alongside or parallel to direction of rotation 17, the edges of the same kind are offset with respect to one another in such a way that an edge 24, facing the rotor, of walls 19 is offset with respect to an edge 25 that faces away from the rotor, in the exemplary embodiment of Figure 6, edge 24, that faces the rotor, being curved, and edge 25 facing away from the rotor running as a straight line. By this measure, the flexibility of honeycomb seal cells 16 and walls 18, 19 of honeycomb seal cells 16 is able to be further optimized.

All the exemplary embodiments shown have in common that at least walls 18 of honeycomb seal cells 16 that run transversely to the direction of rotation 17 of the rotor are placed radially at a slant in the direction of rotation of the rotor. For this, edges 20, 21, which border walls 18 that run transversely to the direction of rotation of the rotor, are offset to one another. Edges 20, 21 run either as straight lines or as curves.

This makes possible a good elastic as well as plastic deformability of the walls of the honeycomb seal cells,

without the walls of the honeycomb seal cells being damaged or having material removed in response to the brushing of the rotor or the sealing fins on the rotor side against the honeycomb seal. The stress on the honeycomb seal may accordingly be reduced, whereby its service life is increased. No undesired enlargement of the gap, that is to be sealed, takes place, and thus a greater sealing effect can be achieved. The sealing device according to the present invention is used especially for sealing a radial gap between the radially inside ends of vanes and a rotor. The honeycomb seals are then assigned to the radially inside ends of the vanes or of corresponding inner cover bands of the vanes, sealing fins assigned to the rotor acting together with the honeycomb seal. Using such a sealing device, it is also possible to seal a gap between the radially outer ends of the rotating rotor blades and a fixed housing. The use of the sealing device is preferred in the compressor region or turbine region of a gas turbine, especially in an aircraft engine.